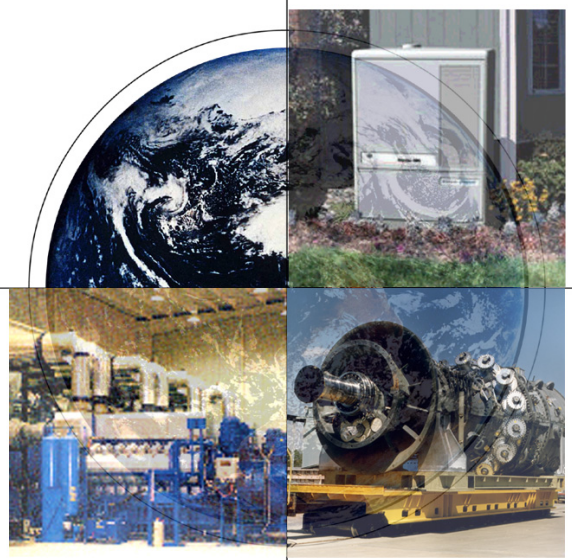
Development of a Fiber Coupled, End Pumped, Nd:YAG Laser Spark Plug



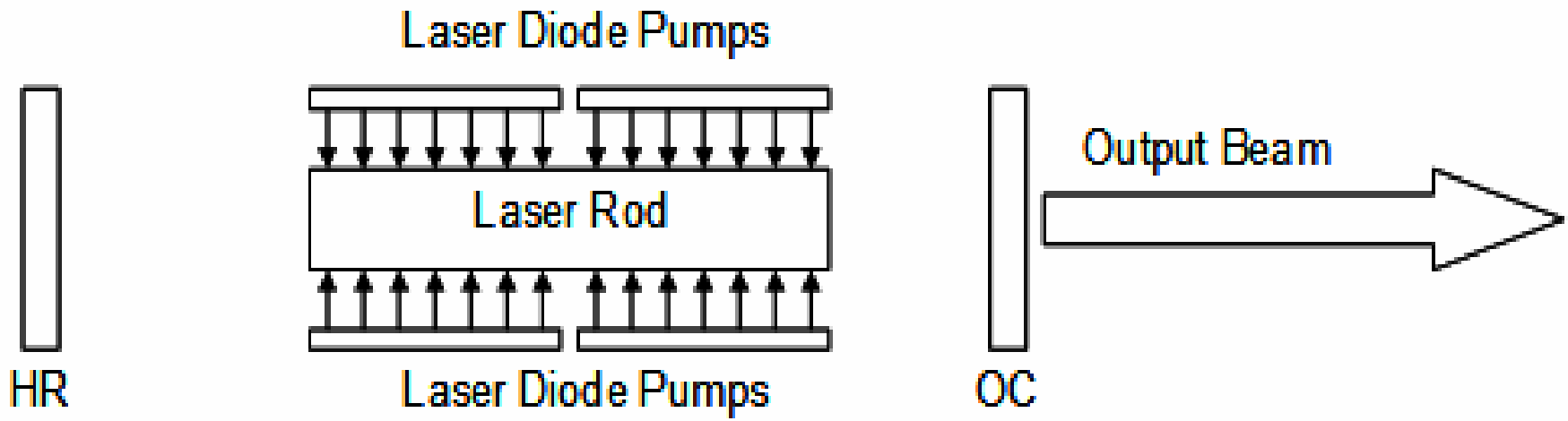
Steven D. Woodruff
Dustin L. McIntyre

National Energy Technology Laboratory

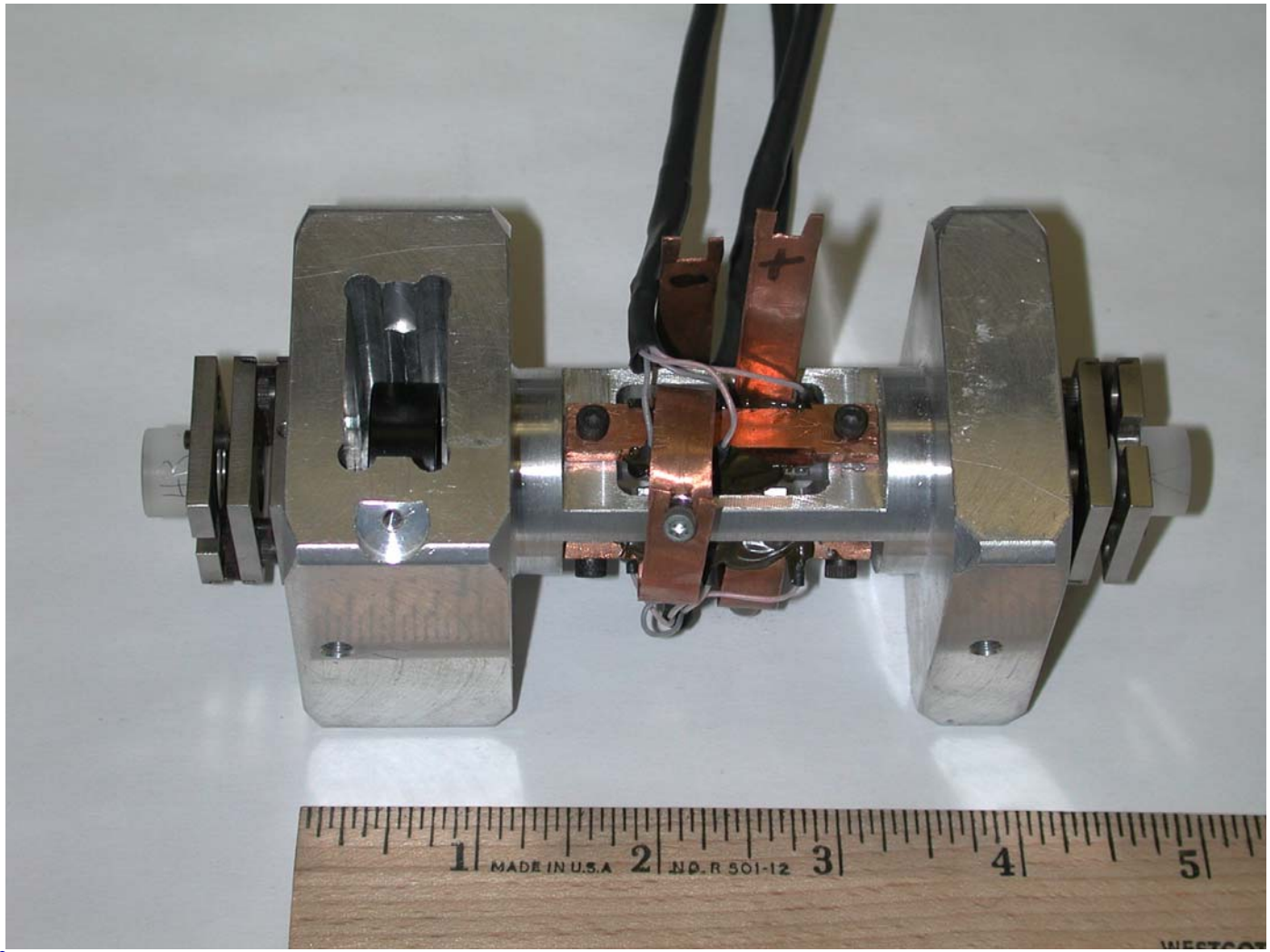
4th Annual Advanced Stationary Reciprocating Engines Conference

September 18, 2007

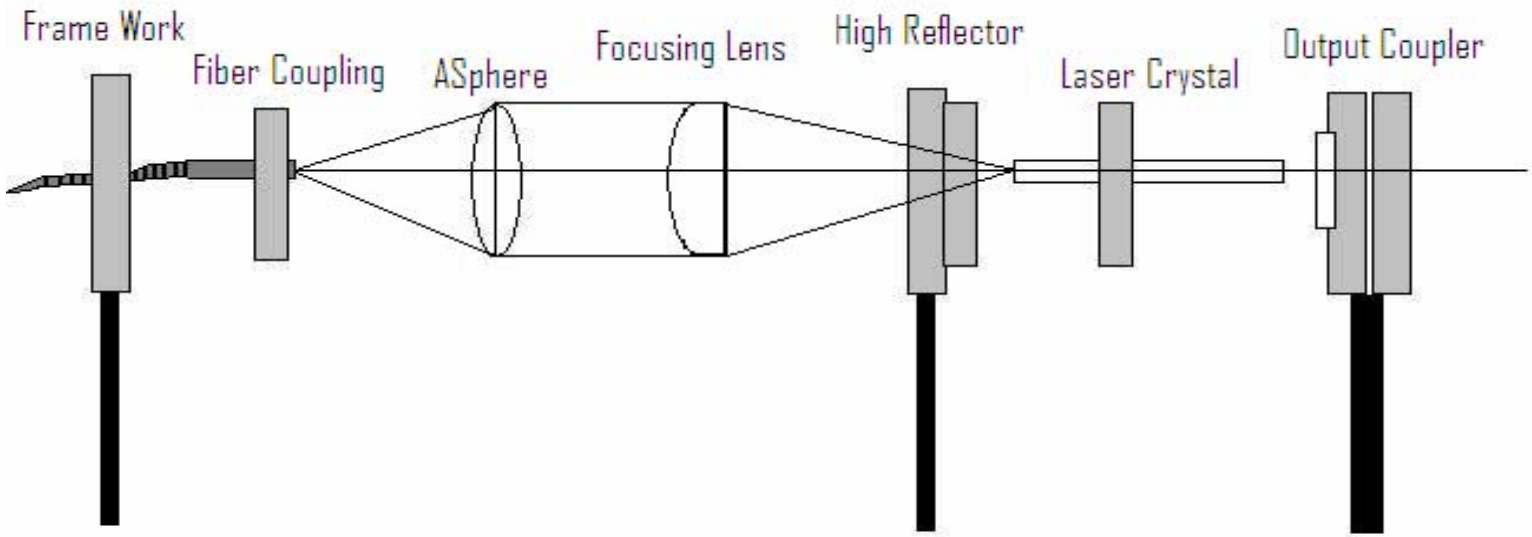
Side Pumped Nd:YAG Laser
The Beginning



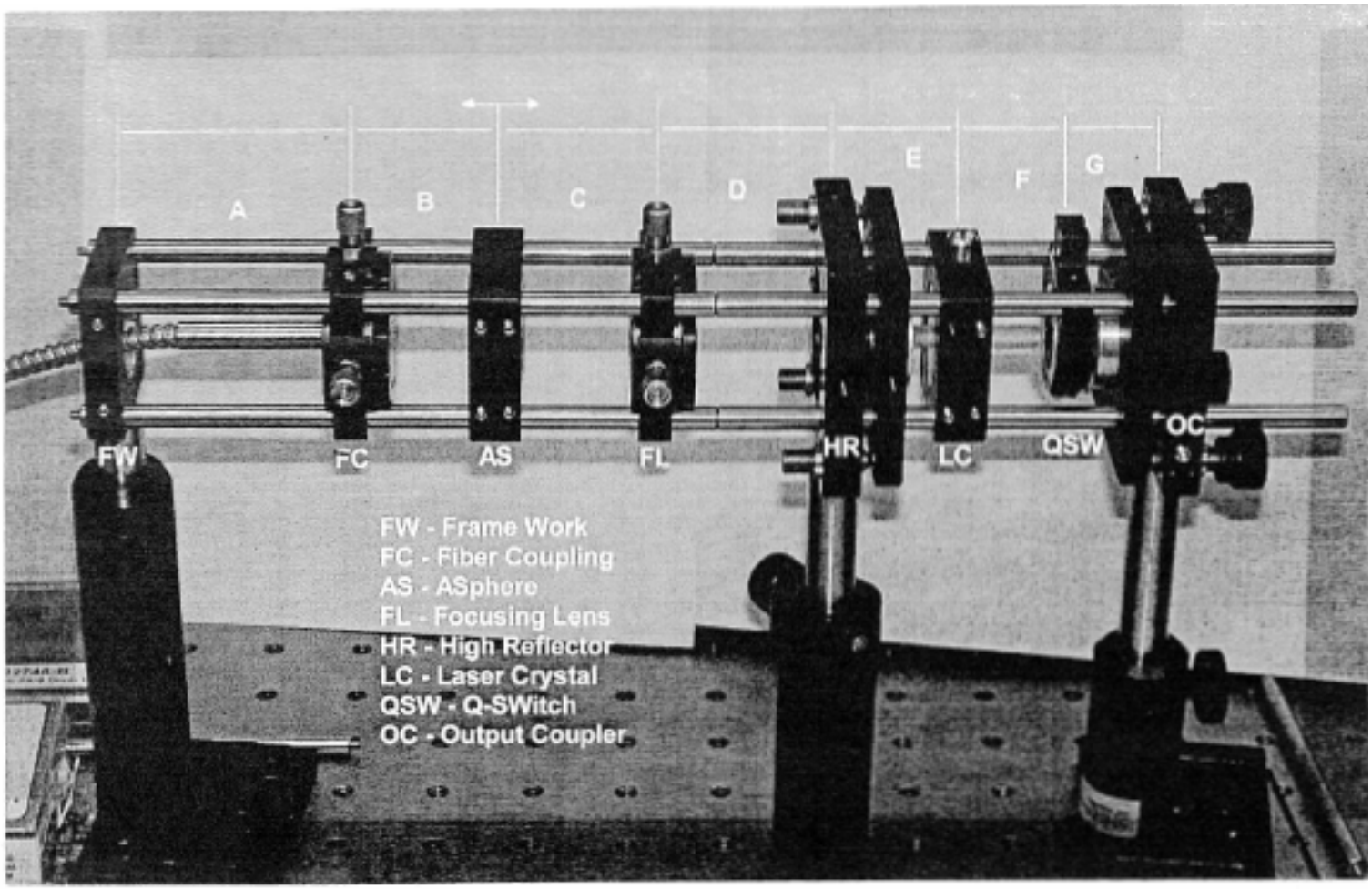
Side pumped laser spark plug



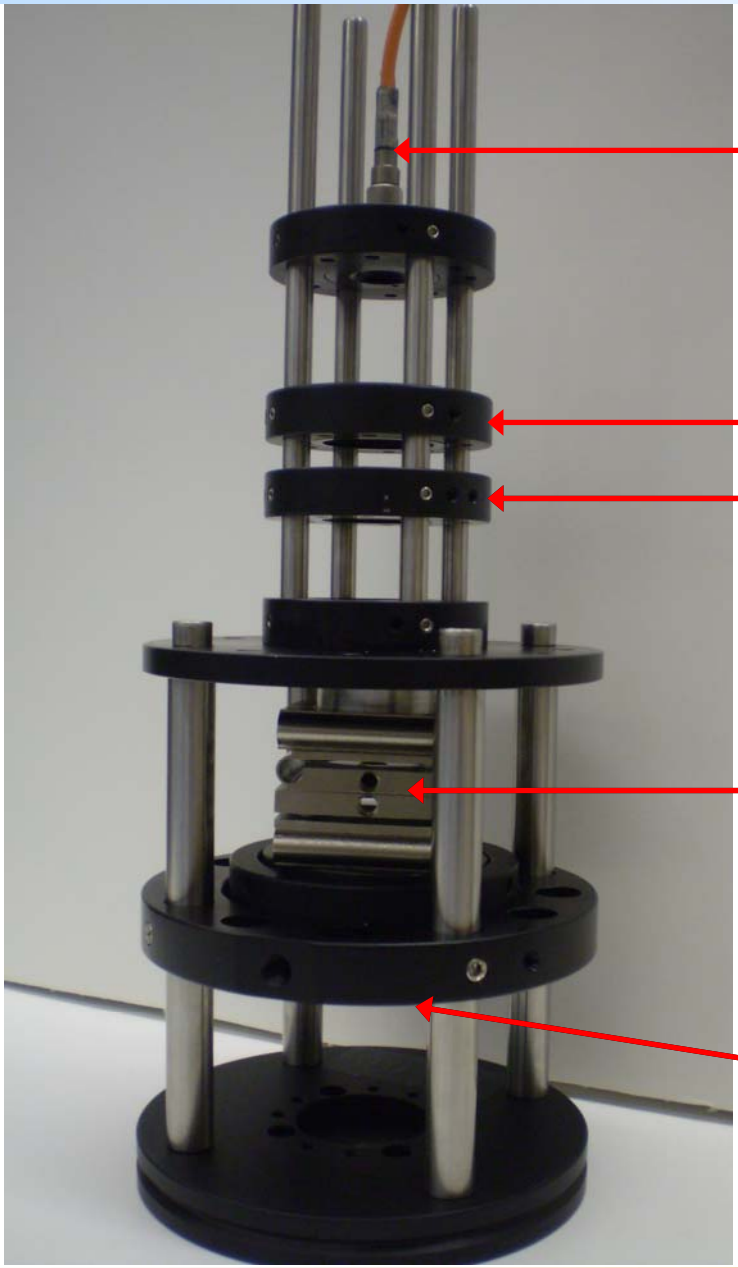
End Pumped Nd:YAG Laser
The Next Step



End pumped, Nd:YAG laser



End Pumped Laser Spark Plug



Pump Optical Fiber

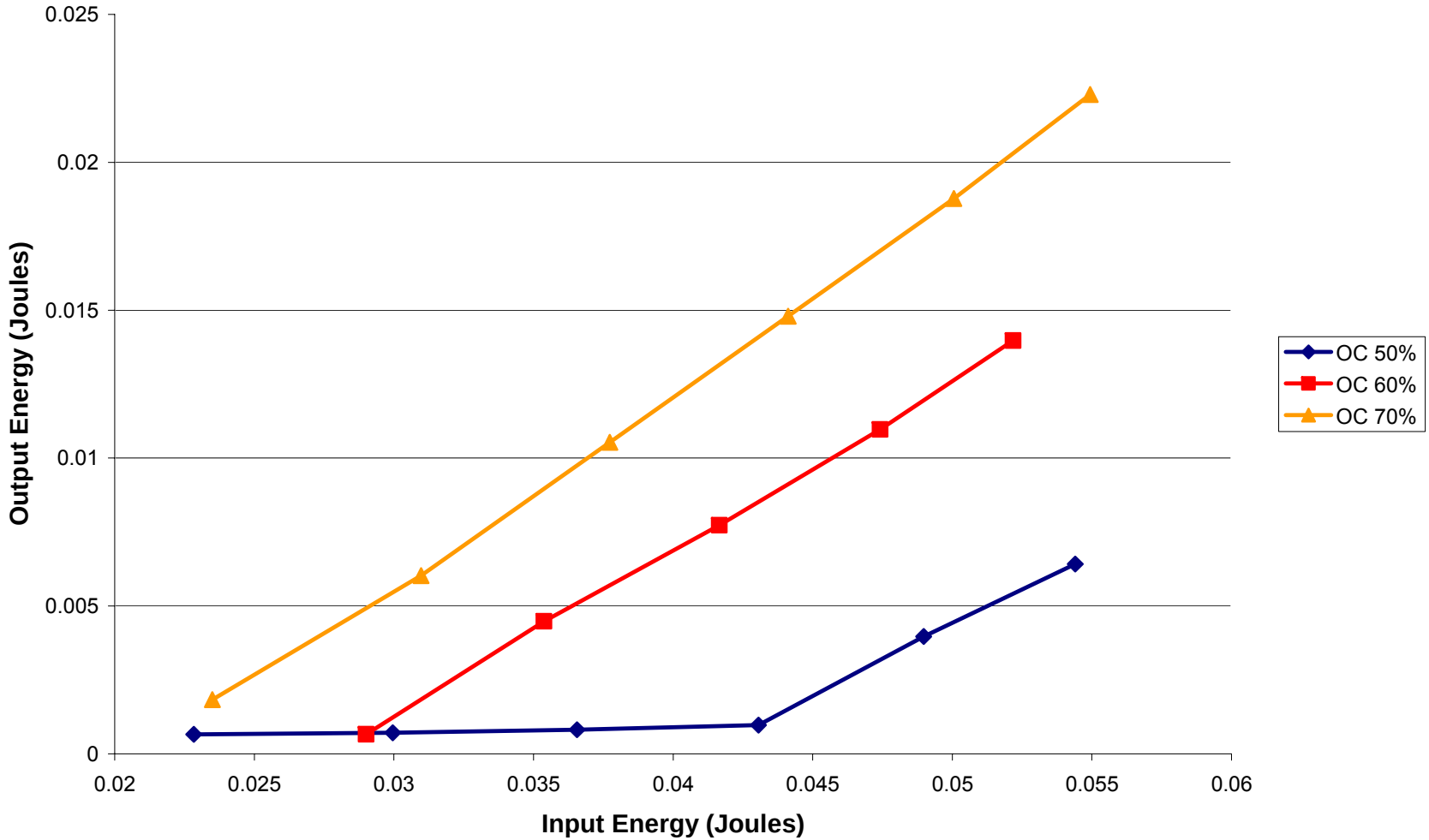
Collimating Lens

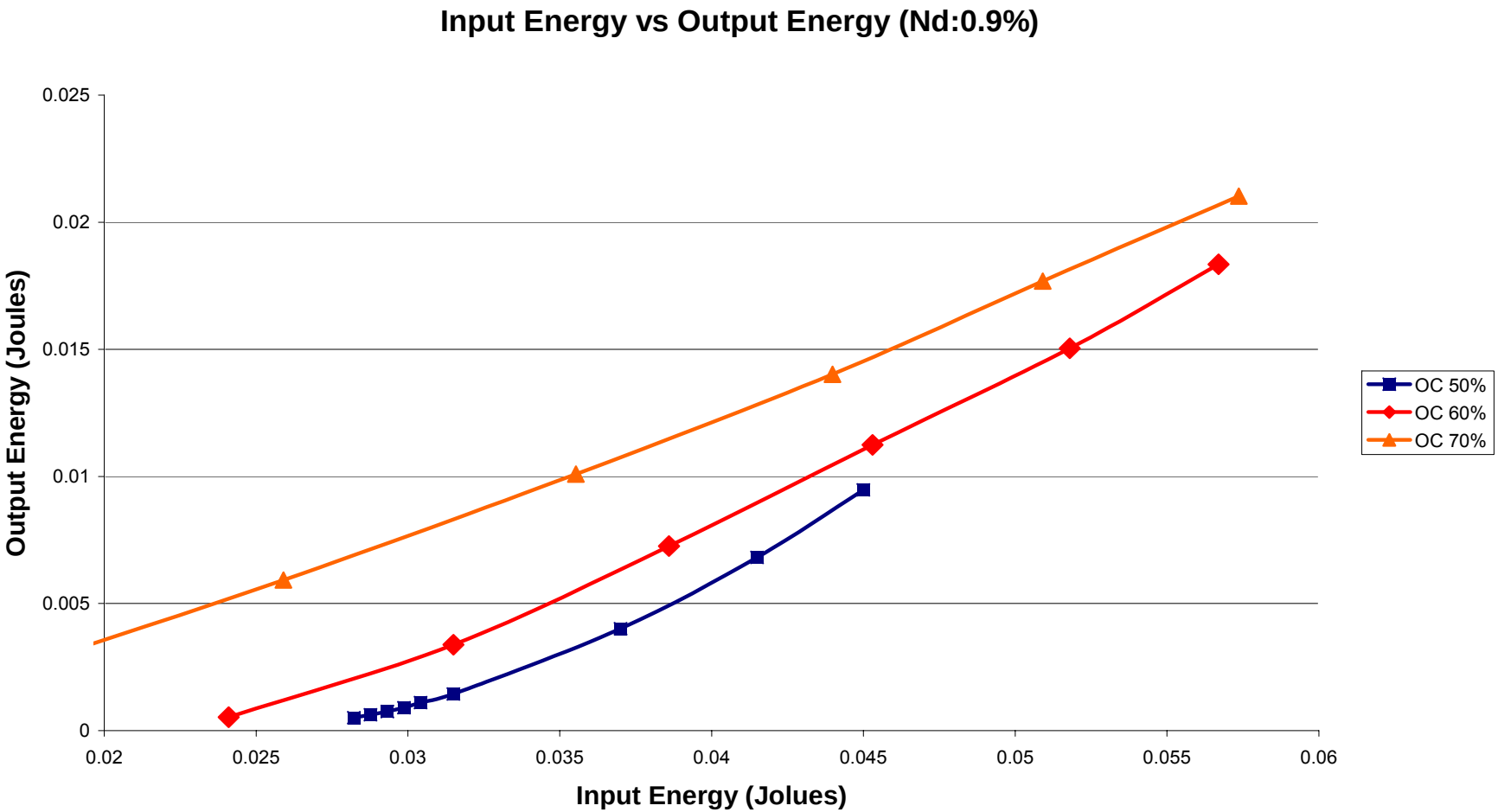
Focusing Lens

Q-switched Nd:YAG Laser

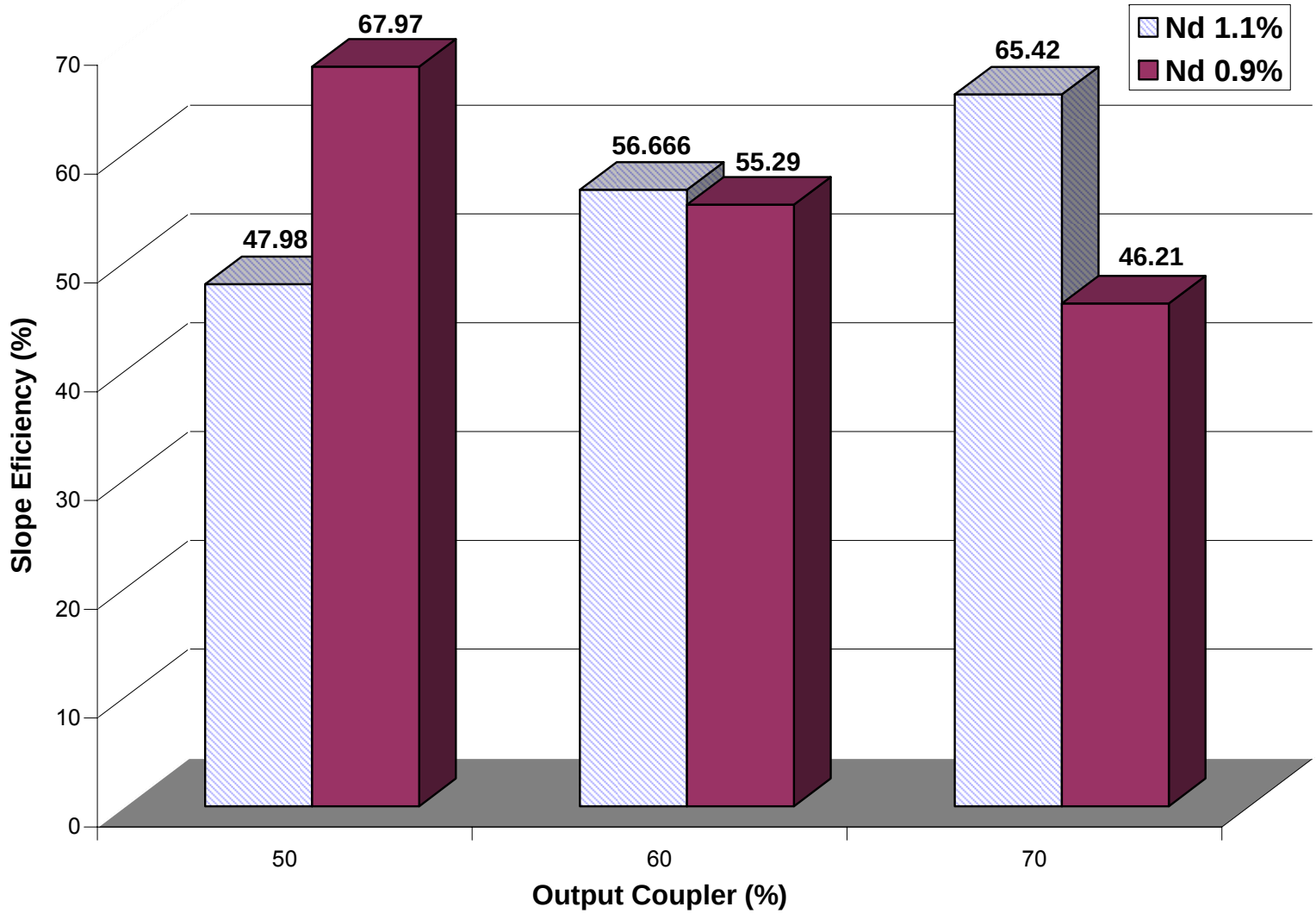
Beam Steering Optics

Input Energy vs Output Energy (Nd:1.1%)

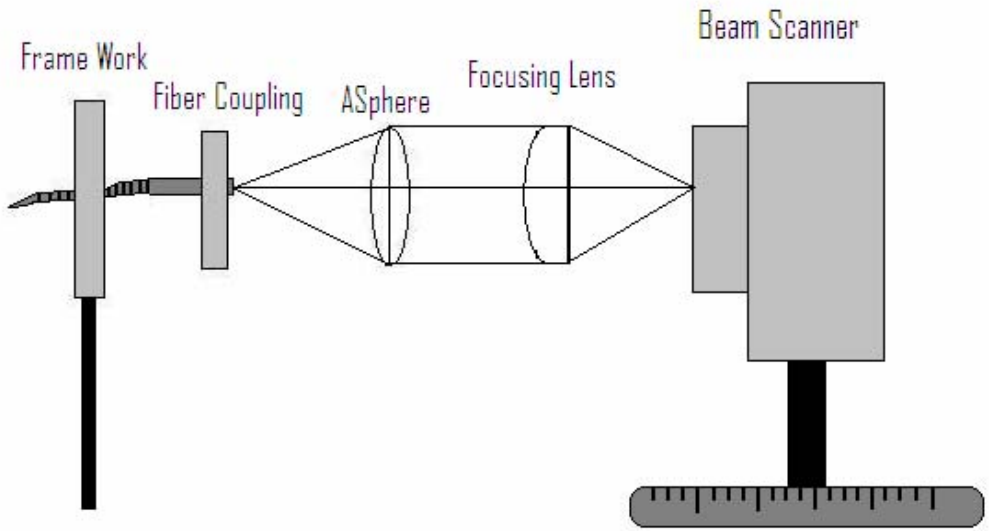



Input Energy vs Output Energy (Nd:0.9%)
Output Energy (Joules)
0.025
0.02
0.015
0.01
0.005
0
0.02
0.025
0.03
0.035
0.04
0.045
0.05
0.055
0.06
Input Energy (Jolues)
OC 50%
OC 60%
OC 70%

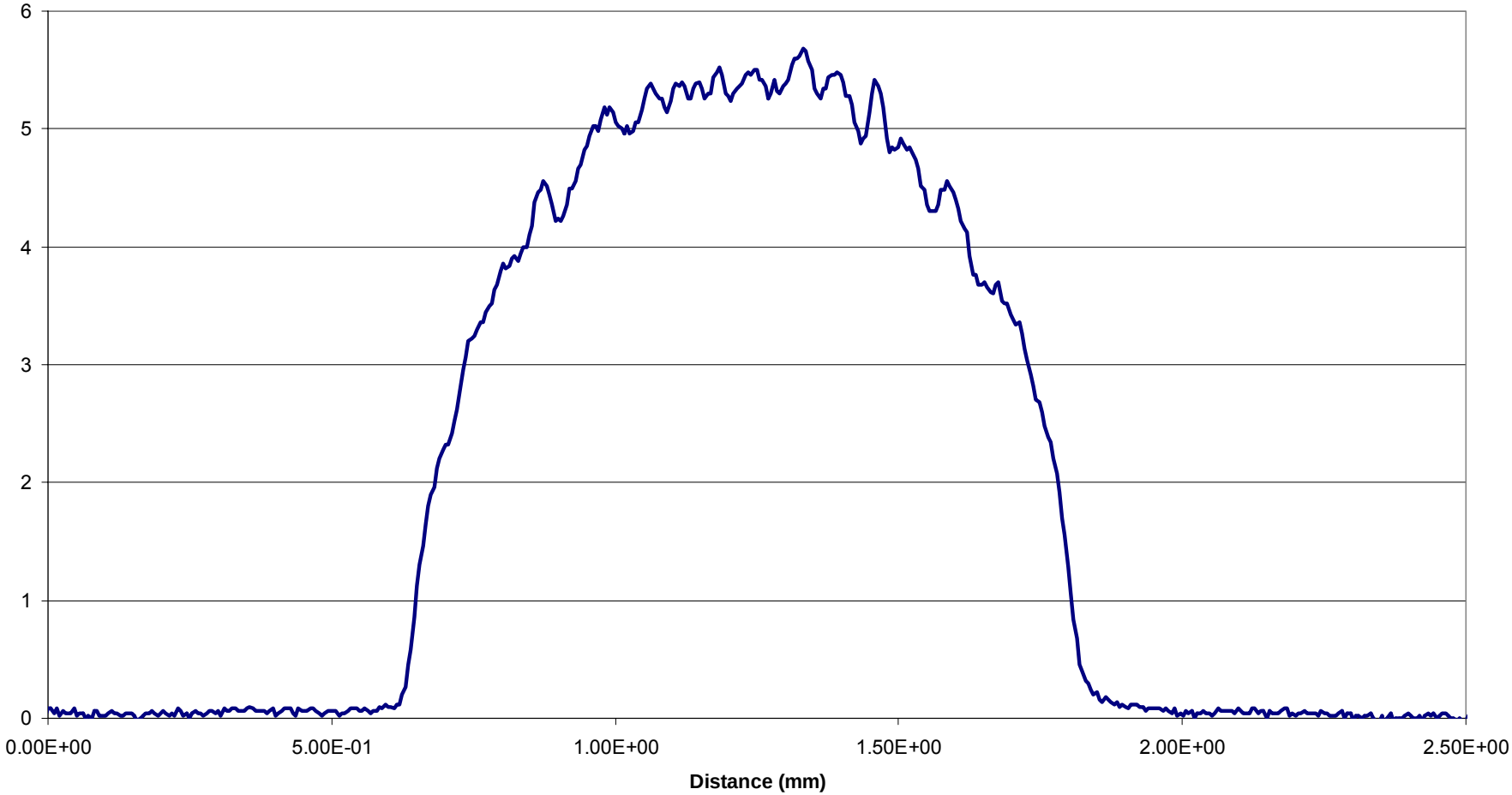
End Pumped Laser CW Output Analysis



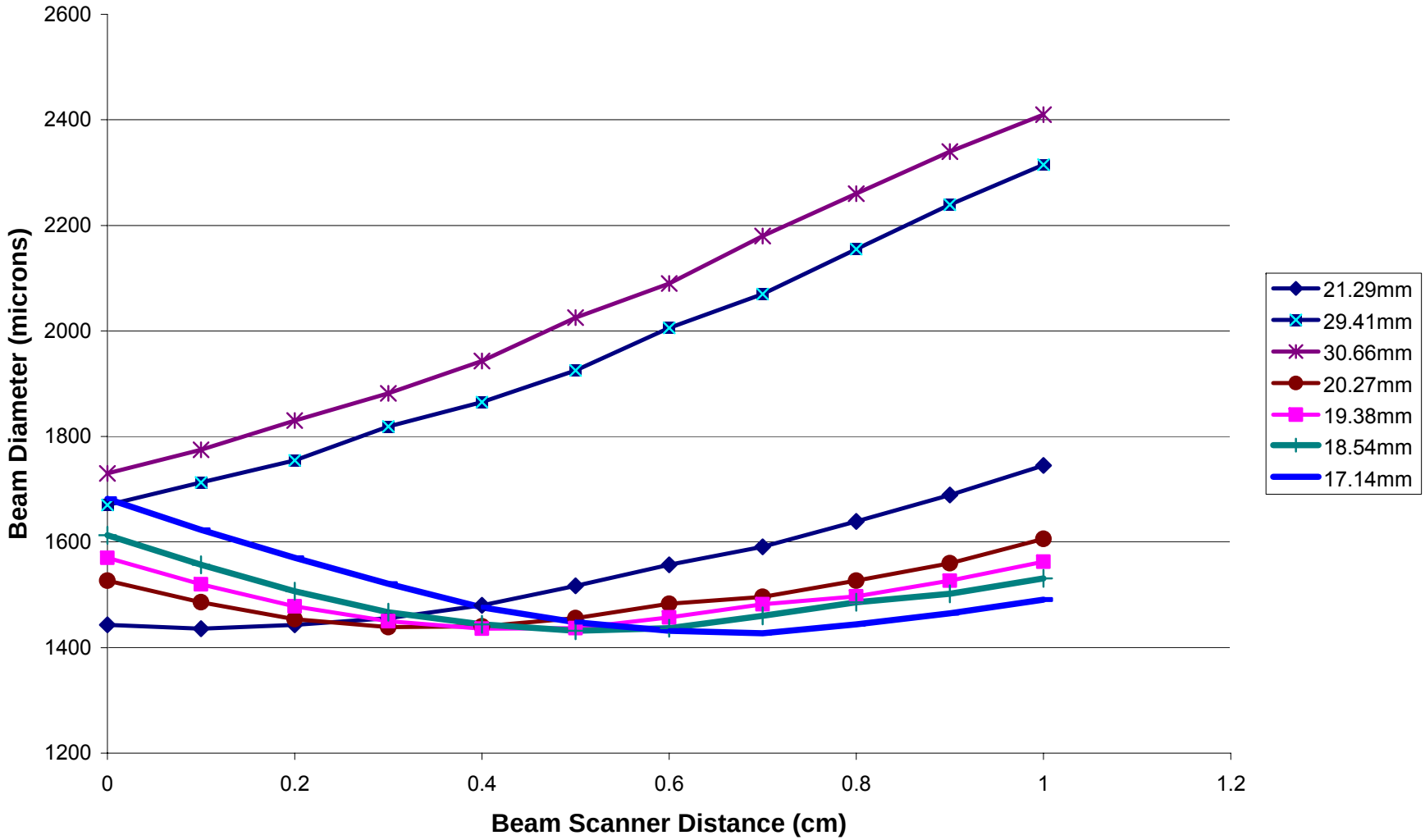
Pump beam scanning configuration



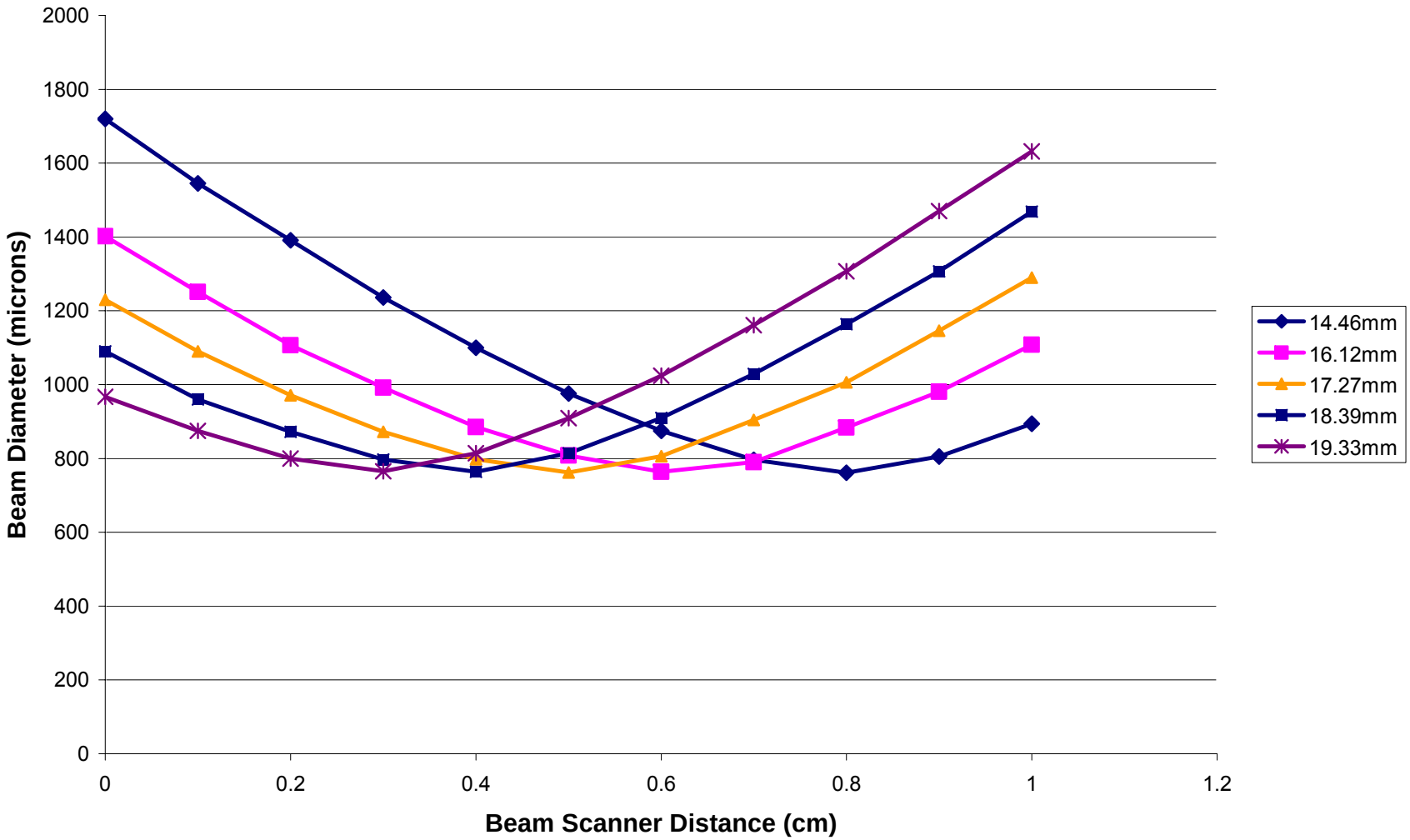
Beam Shape
40 mm collimating lens, 75 mm focusing lens



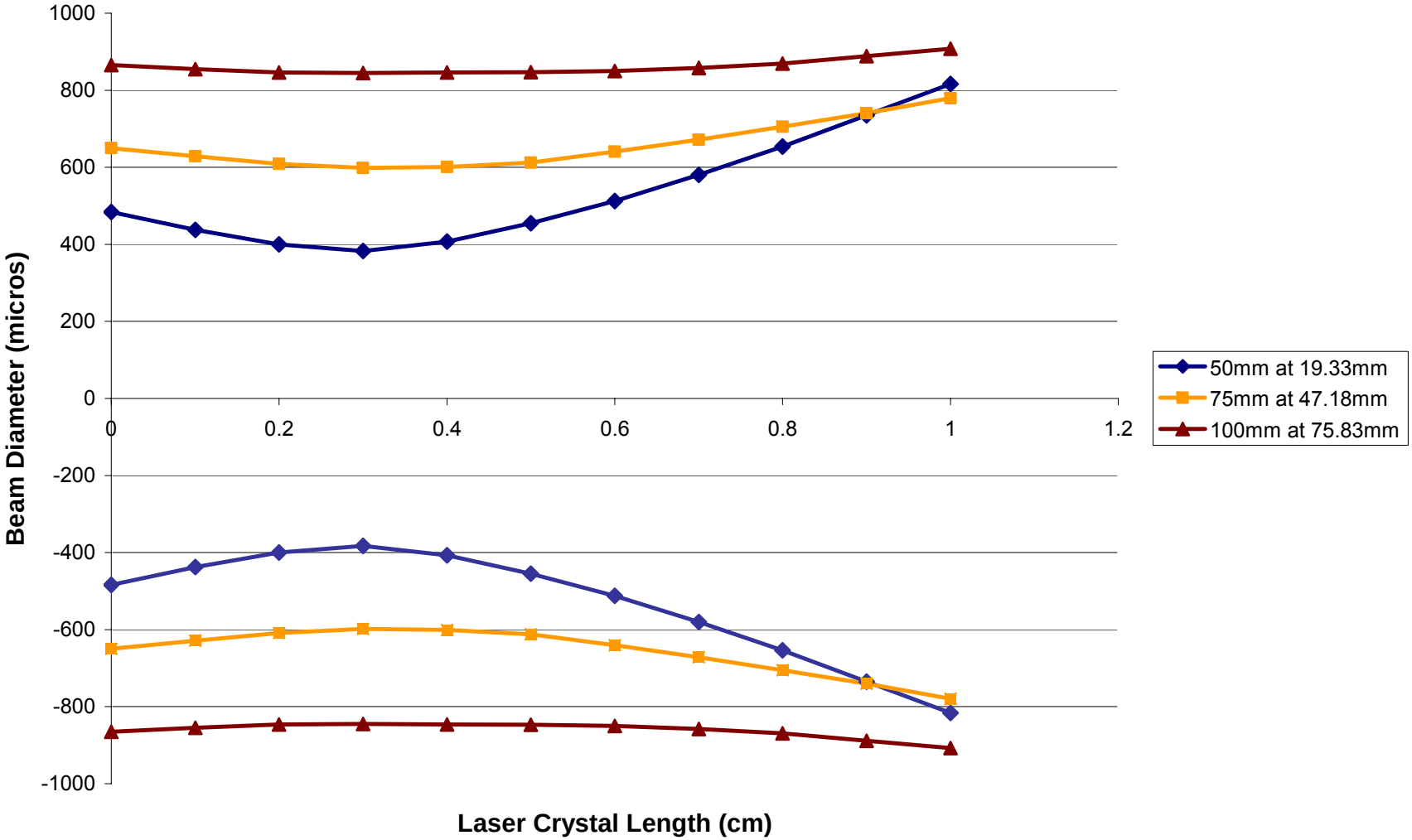
Fixed Asphere - Beam Diameter w/ 50mm



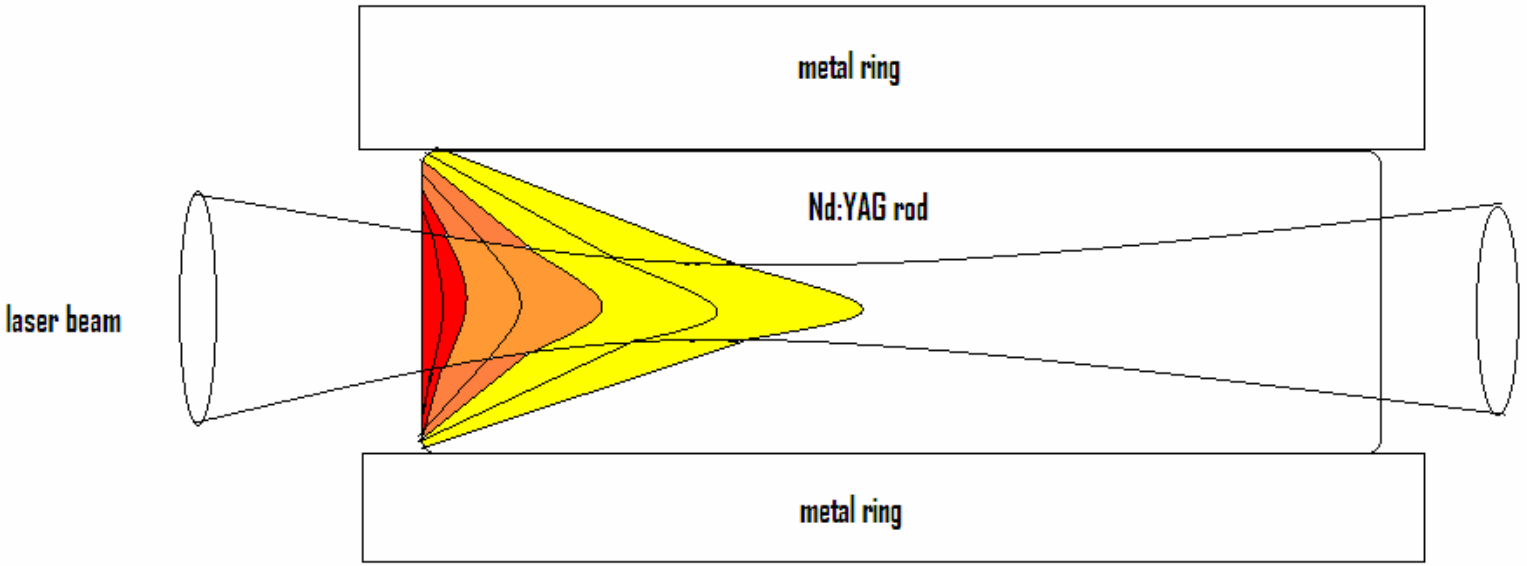
Fixed FL 40mm - Beam Diameter w/ 50mm



Optical Focus Position Inside Laser Crystal



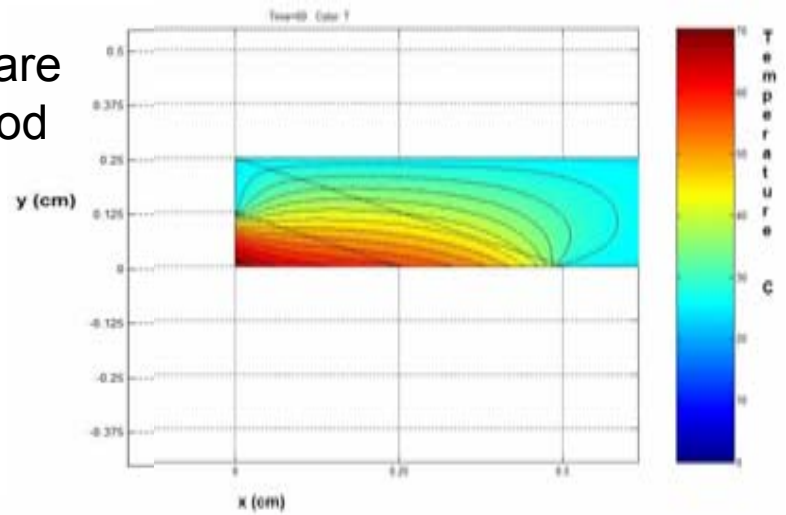
Thermal management parameters

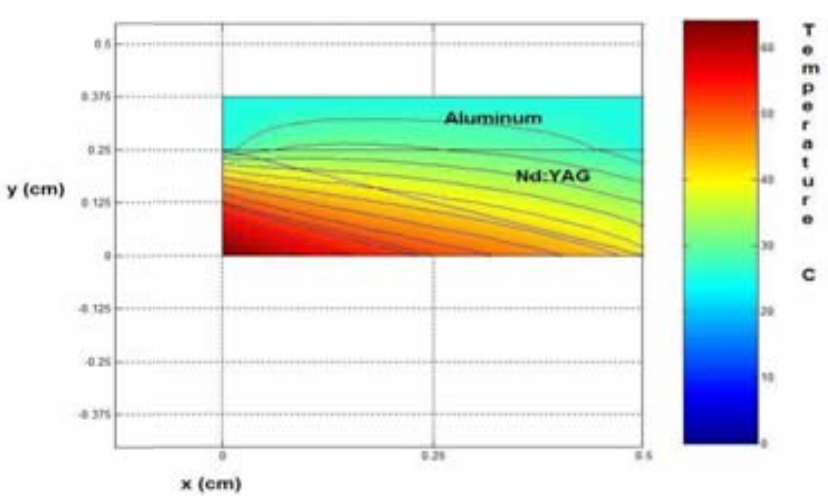


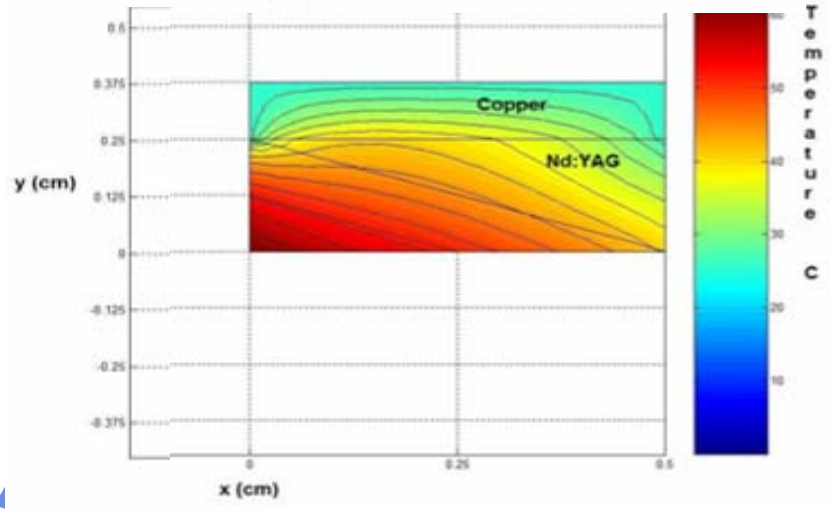
Material	ρ – density $g \cdot cm^{-3}$	K - thermal conductivity $W \cdot cm^{-1} \cdot K^{-1}$	C specific heat $J \cdot g^{-1} \cdot K^{-1}$
Nd:YAG	4.56	0.14	0.59
Aluminum	2.70	2.37	0.89
Copper	8.96	4.01	0.38
Silver	10.5	4.29	0.23

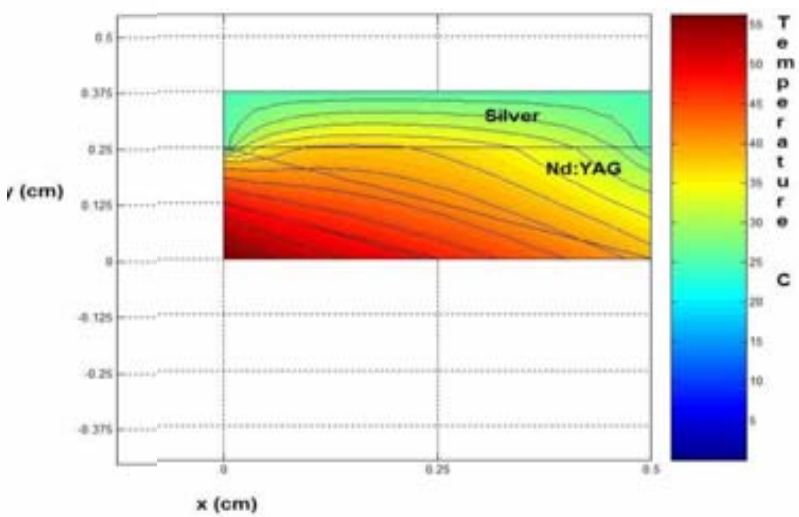
2-D view of temperature distribution

Bare Rod

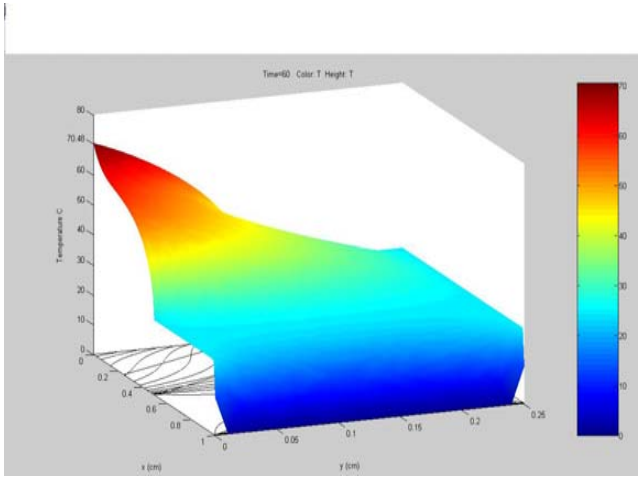




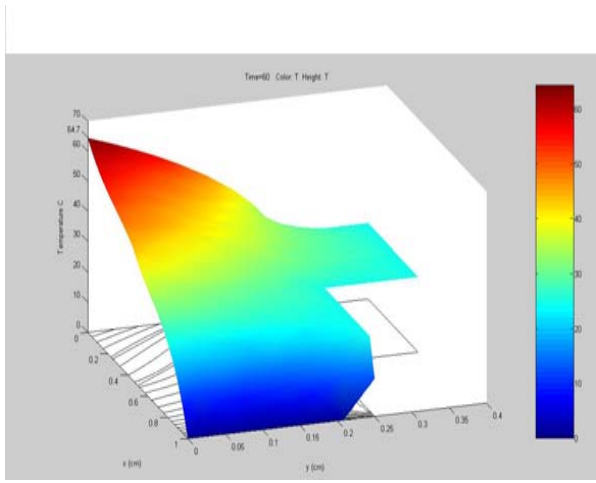




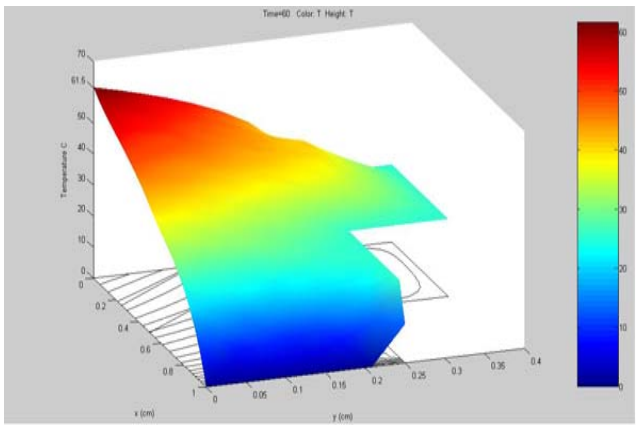
3-D view of the temperature distribution



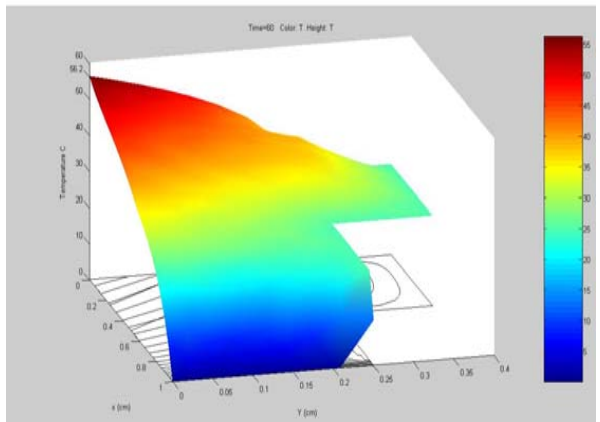
Bare rod



Al ring

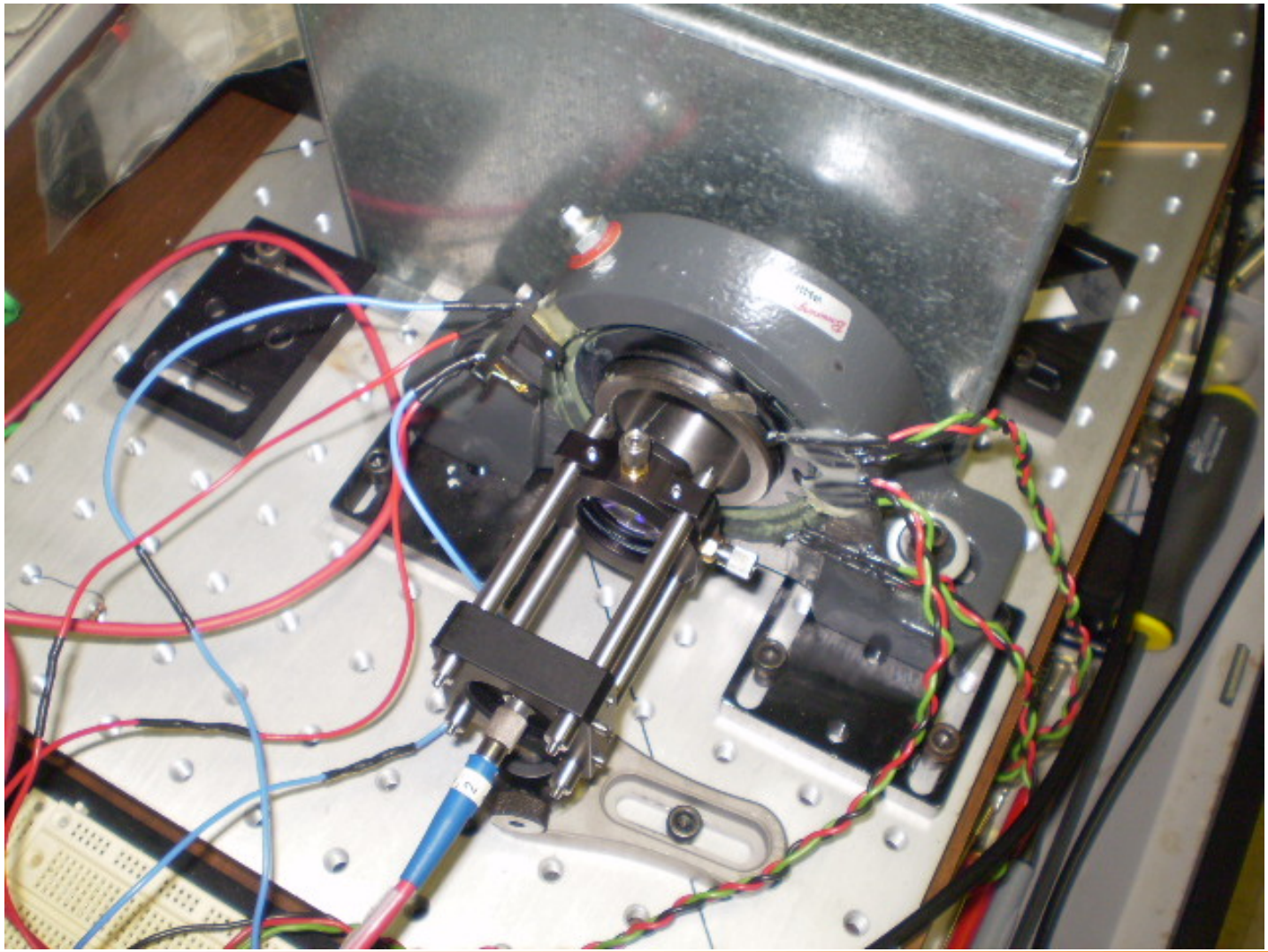


Cu ring

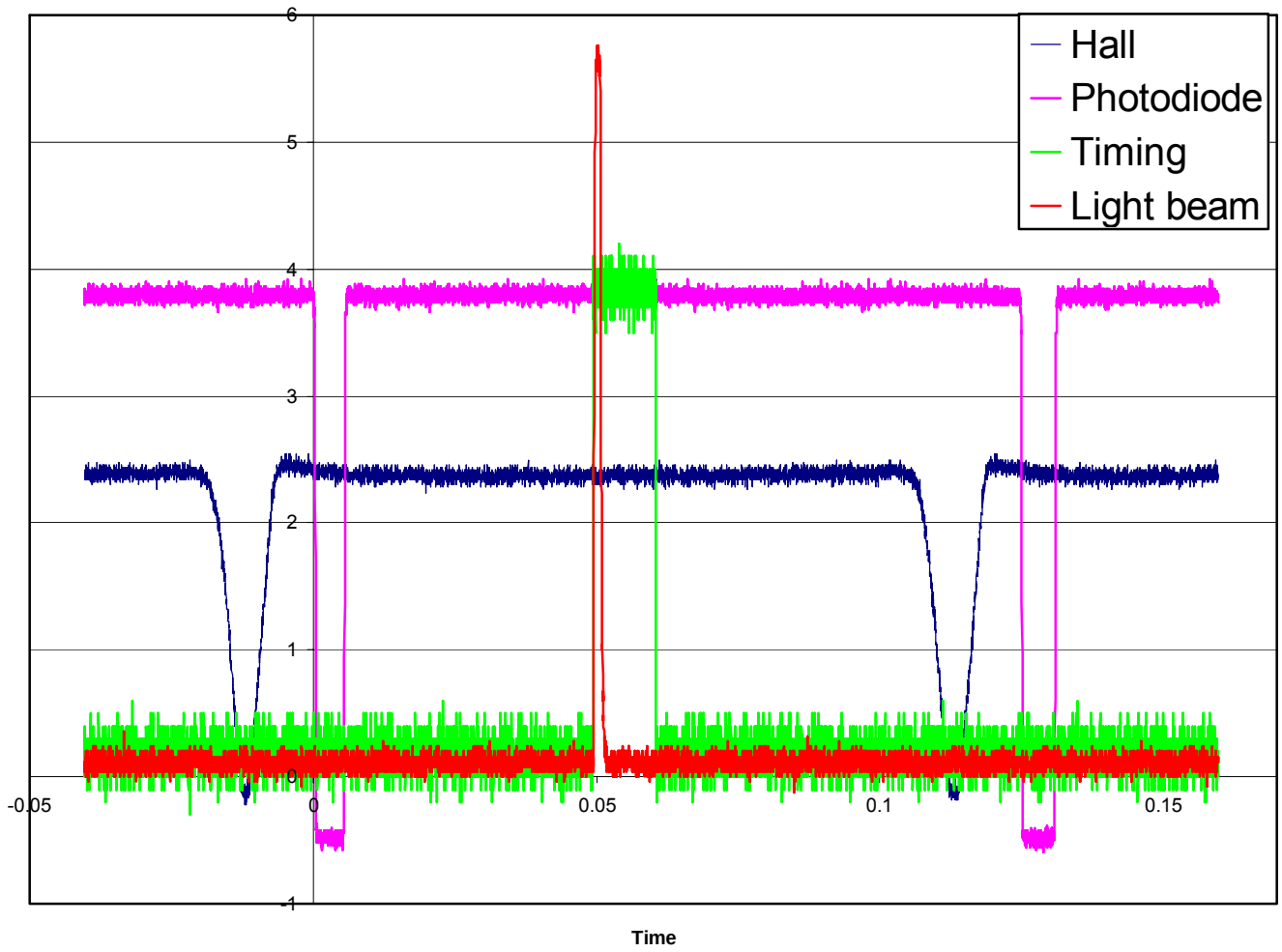


Ag ring

Optical Distributor



Distributor Signals



Current Status

- Pulse energies of >8 millijoule
- Pulse width of 5-6 nanosecond
- M^2 to be determined
- Sapphire and fused silica lens assemblies under construction
- Costs are dropping…

To Do List

- **Test laser components**
  - Test higher concentrations of Cr:YAG
  - Test lower reflectivity output couplers
  - Cool the YAG rod
- **Test 200 watt, 400 micrometer fiber laser**
- **Test plug lens assemblies**
- **Engine test**

Laser Sparkplug Costs

- **Single Unit, OTS costs**
  - Laser pump source - ~$12k
  - Pump power supply - ~$7k
  - Optical fiber - <$30/m
  - Distributor - ~$300 + a motor driver
  - Laser plugs ~$800 + mounts

- **Source + Distributor <$20k + plug costs**
- **Should drop with mass production**

Thanks to MLEF Students

- Ricardo Velez – Univ. of Mass.
- Adrian Comacho-Berrios – Univ. of Mayaquez
- Candace Cobb – Norfolk Univ.